The Continued Development of The Third-generation Shallow Water Wave Model "Swan"

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LONG-TERM GOAL

The long-term goal of this effort is to provide a commonly accepted third-generation wave model for shallow water to the international community of scientists and engineers for the purpose of basic research and operational wave computations (public agencies such as army, navy, harbor authorities, universities and private industry such as oil companies, engineering companies, etc.).

OBJECTIVES

The main objective is to support and assist the continued development, validation and verification of the SWAN model and its use in operational conditions. The development will be based on new scientific insights in the evolution of waves in shallow water. The verification and validation will be based on field observations and laboratory experiments supplemented with numerical experiments. Operational use will be supported with first-line assistance and diagnostics.

APPROACH

The continued development of the SWAN model is envisioned as a community effort of the wave modelers presently working in this field of technology, most of whom coordinate their efforts in an international forum called WISE (Waves In Shallow Environments, established in 1993 as the shallow-water follow-up of the WAM group and the HISWA group).

We provide support and assistance to these and other ONR-designated investigators. We assist in the installation of SWAN under conventional operating systems (also as a sub-model in larger systems of models such as atmospheric and ocean circulation models). The present extensive and detailed documentation (about 100 pages) is being supplemented with introductory documentation. Questions of users are answered and errors are located and repaired (often in response to problems encountered by the users). Updated program codes (including new cycles) are communicated to all registered users. This support is operating through electronic-mail facilities.

We are collaborating with ONR-designated investigators to improve the model technology of SWAN. We will independently add wave reflections (including scattering) to the model for sub-grid elements (e.g. breakwaters) and coastlines.

This approach is essentially a continuation of the development of the SWAN model over the years 1992 - 1996 by J.A. Battjes, L.H. Holthuijsen and N. Booij and their Ph.D. students. This consists of designing, implementing and testing a fully spectral third-generation wave model for shallow water

with a fully implicit propagation scheme. Battjes supervises the scientific developments, Booij supervises the numerical developments. Holthuijsen is responsible for project management and overall supervision. In addition, IJ. Haagsma carries out the upgrading of the computer code as regards system requirements and provides first-line support for the users. A. Kieftenburg carries out the upgrading of the computer code as regards scientific and numerical aspects and she shares the first-line support with Haagsma.

WORK COMPLETED

Support and assistance

Installation, nesting and linkage:

a) A new version of SWAN (30.75) was released on 02-04-'98. New features are:
   - -It permits computations in one-dimensional stationary mode.
   - -It permits the inclusion of wave-induced set-up in one-dimensional mode.
   - -It accepts and produces directions in nautical convention in addition to the previous Cartesian convention.
   - -It accepts spectra that vary along the spatial boundaries.
   - -It warns against unavoidable boundary discrepancies.
   - -There is greater freedom in choosing the representation of the physics.
   - -The millennium problem is solved for SWAN.
   - -Coding bugs have been fixed.
b) The SWAN homepage on the Internet has been regularly updated.
c) Since the release of SWAN in public domain on April 1, 1997, it has been downloaded by over 125 institutes.
d) In the report period approximately 80 queries of users about SWAN installation have been answered: general information (30), program bugs (15), installation (15), code (5) and usage (15).
e) The testing of the SWAN code at compiler level with Lahey Compiler V3.50e (severest level) was continued.
f) The nesting of SWAN into the WAM model is now based on the WAM Cycle 4 version from MPI (Hamburg).
g) SWAN is being tested on supercomputers.

User documentation:

a) An introductory user manual of SWAN is nearly finished. It is generated by suppressing detailed information in the regular user manual (both are in WP7.1 format). An index is added to this manual.
b) The user manual has been updated to fit the new SWAN release, and is now available in Word Perfect 7 (.wpd), PostScript (.ps), and Portable Document Format (pdf).
c) The implementation manual has been updated, and is now available in Word Perfect 7 (.wpd), PostScript (.ps), and Portable Document Format (pdf).
d) A coding protocol for SWAN has been formulated and released on the SWAN home page.
e) A user discussion group on the SWAN home page is under development.
f) A configuration group for SWAN to advise the SWAN steering group on requirements for system configuration of SWAN is under discussion.
g) A graphical interface for the one-dimensional option of SWAN is in preparation (main effort to be spent elsewhere and funded by Rijkswaterstaat)

User support, diagnostics and repairs:

a) Several (minor) errors in the SWAN source code have been detected (particularly by different compilers) and repaired.
b) One type of compiler warning (with a very large number of occurrences) has been avoided by using an EQUIVALENCE statement to modify the type declaration of variables in the current pre-release SWAN.
c) The updating of the system documentation (headers of the subroutines) has continued.
d) A first version of an extensive test bank with academic cases (with analytical solutions) and real cases (with observations) has been developed (in consultation with CERC where a supplementary test bank is being formulated). Rijkswaterstaat commissioned Alkyon to develop this test bank.

Improvement of model technology:

a) The option of computing wave induced wave set-up in two-dimensional mode has been added in a pre-operational version of SWAN. It is being tested by Delft Hydraulics (funded by Rijkswaterstaat).
b) Nonstationary boundary conditions have been defined and implemented in an experimental SWAN version (after SWAN users were requested to comment on the input format for these boundary conditions, particularly as regards the configuration of SWAN in larger systems).
c) Time dependent wave growth in idealized and non-idealized cases has been tested (e.g. the GORBUSH storm in the Mediterranean; M.Sc. thesis work).
d) After testing SWAN on surfzone observations in Japan (Kashima), the depth-induced breaking and the triad wave-wave interactions formulation have been modified in an experimental version of SWAN (memory added by taking the up-wave averaged depth and by adding an f^2 distribution to the Battjes-Janssen term).
e) The development of a third-order propagation scheme for SWAN is supported. Following recommendations from this Delft group and from G. Stelling, and additional tests, J. Kaihatu and E. Rogers a scheme has been selected, implemented and tested by them in an experimental SWAN version (funded under another BE program).
f) A self-scaling high-frequency cut-off frequency in SWAN has been formulated analogous to the cut-off frequency in WAM (the difference is that in SWAN the mean frequency of the wind input term is used for the scaling). It is presently being implemented by Delft Hydraulics (funded by Rijkswaterstaat) under supervision of Delft University.
g) The curvi-linear grid capability of SWAN is being tested by Delft Hydraulics (funded by Rijkswaterstaat and supervised by this Delft group).
h) SWAN has been implemented for DUCK (USA) and DELILAH cases are being tested (M.Sc. thesis work).
i) An option for 1D-computations has been developed and added to the public domain version.
j) Various options to simulate diffraction have been added to an experimental version of SWAN.
h) The options of 1-D and 2-D wave-induced set-up and nonstationary boundary conditions have been implemented and are being tested.

RESULTS

The significance of the above completed work is that the most advanced wave model to date for coastal applications (horizontal scales with a maximum of 25 km, and water depth with a maximum of 20 m) and its user support have been made available free of charge to the international community of scientists

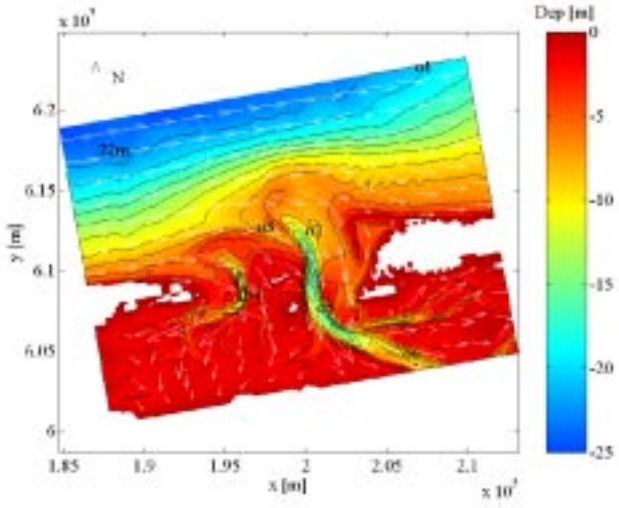

Fig.1 Bathymetry and currents at the Friesche Zeegat (Oct. 9, 1992 05:00 UTC)

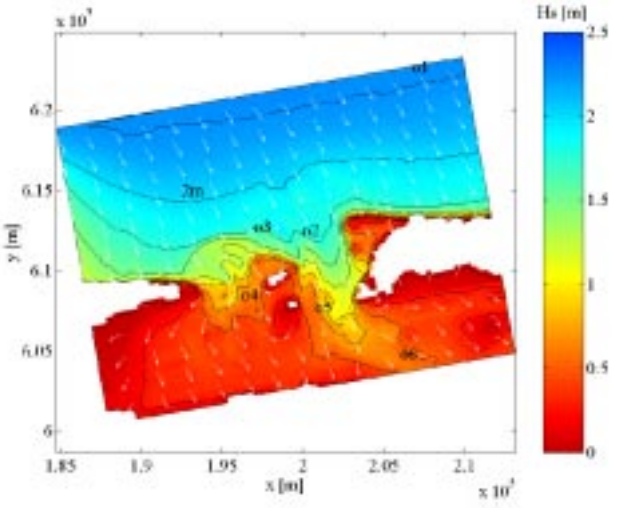

Fig.2 Significant wave height and wave direction at the Friesche Zeegat (Oct. 9, 1992 05:00 UTC)

and engineers. In this second year over 100 institutes from all over the world are using the SWAN program.

As an example of SWAN's capabilities the bathymetry and currents at the Friesche Zeegat are shown in Figure 1 (SWAN input); the calculated significant wave height and wave direction, given a 2.5 m boundary condition at the 'upper limit' of the computational domain, are shown in Figure 2 (SWAN output).

IMPACT/APPLICATION

SWAN provides scientists with a common platform for their research of the generation, propagation and dissipation of wind surface waves in shallow water. The community SWAN model facilitates the integration of these aspects and avoids the need to develop supplementary models in each individual research project. Moreover, with the support provided here, the results of such projects will be implemented in a fully operational cycle of the SWAN model thus serving the community in general (for this purpose the SWAN model is freely available to all). It therefore also provides a common standard for engineering applications accepted by a large number of institutions worldwide.

TRANSITIONS

The SWAN model is available free of charge to anyone at request (essentially in the public domain). Its use is supported by the original authors under this project. SWAN is aimed at operational use by such government agencies as army and navy, national weather services and others, in the USA and abroad. Also private industry is using SWAN, mostly to determine the coastal wave climate for the purpose of design of structures and off-shore operations.

RELATED PROJECTS

Considerable efforts are being carried out by others to further develop the SWAN model. In the USA this is coordinated mostly through the DRI and BE programs of ONR. In Europe, similar efforts (on a

smaller scale) are carried out by groups of investigators funded by the EC and by national governments (notably in the Netherlands, Germany and England). The nature of these efforts is both theoretical and empirical and require extensive field work and computer experiments. The level of funding is several million US dollars per year.

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